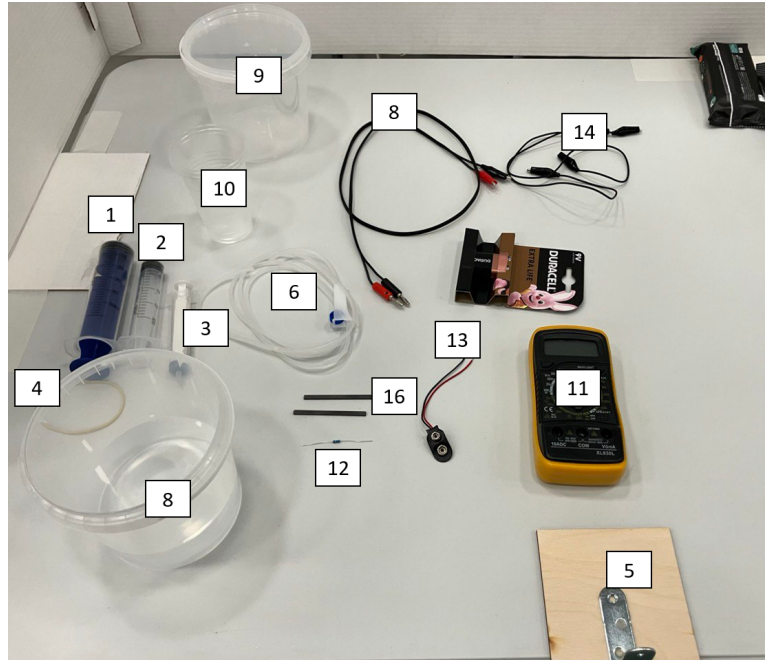


M1B - Ionic conductance

Оборудование:

1. Syringe 50 ml
2. Syringe 20 ml
3. Syringe 10 ml
4. Rubber band
5. Fixed on the table wooden stand
6. IV drip hose with length $L = 130$ cm
7. Plastic jar with sodium chloride (NaCl) solution, concentration 2.0 mol/l
8. A bottle of pure water
9. Two plastic cups
10. Multimeter
11. Resistor
12. PP3 9 V battery
13. Two pairs of «Banana-Alligator» wires
14. Pair of graphite electrodes



One mole of substance is the amount of substance that contains $N_A = 6.02 \cdot 10^{23} \cdot 1/\text{mol}^{-1}$ molecules.

At the beginning of the last century, Peter Debye and Erich Hückel developed the first theory describing the behavior of charged particles surrounded by a large number of other charged particles. Although this approach quantitatively explained many phenomena in plasma and electrolytes, many fundamental questions related to the behavior of ions in solutions remain unresolved.

B1 Determine inside cross-sectional area S of IV drip hose.

0.5

B2 Determine the resistance R of the provided resistor and the internal resistance R_V of the voltmeter. Assume that R_V is independent of its operating mode.

0.5

For the theoretical description of microscopic phenomena in an electrolyte, it's convenient to use the specific conductance κ instead of the specific resistance ρ . The resistance R of a long wire of length L and cross-sectional area S is expressed in terms of specific conductivity as:

$$R = \frac{L}{\kappa S}.$$

If the current I uniformly flows through the cross-sectional area S the current density $j = I/S$ is introduced.

B3 Indicate the units of κ .

0.5

Note that there is always a parasitic voltage at the solution-electrode interfaces due to various chemical phenomena, which may change slowly over time. Your further measurements must take into account the presence of this voltage. It is best not to measure the parasitic voltage directly, nor to include it in formulae for calculations.

Only graphite rods should come into contact with the electrolyte, as their surface is much more inert than metal surfaces.



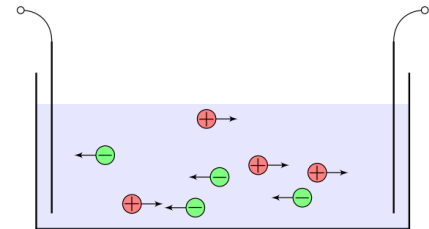
B4 Sketch the setup you will use to measure the specific conductivity κ . Explain any details of the measurement procedure **ONLY** using diagrams. Measure the dependence of the solution's specific conductance κ of the solution on the molar concentration c of the salt. Obtain at least 10 data points. *Note:* In the setup for measuring κ , you must clearly understand how the currents are distributed in the region of space where the most of the applied voltage drops. **4.0**

In the solution, the salt NaCl dissociates completely into charged ions Na^+ and Cl^- . That is, in a salt solution of molar concentration c , the salt exists as sodium ions Na^+ with concentration c and chloride ions Cl^- also with concentration c . The charge of the ions is $\pm e$, where $e = 1.60 \cdot 10^{-19}$ C. Further in the problem, we will refer to the sodium ion simply as a positively charged ion and assign it the index «+», and the chloride ion as a negatively charged ion and assign it the index «-».

Both types of ions, begin to move under the influence of an external electric field \vec{E} , creating an electric current. Any object moving in a fluid experiences a viscous frictional force $\vec{F} = -\mu\vec{v}$, where the quantity μ is called the mobility. The viscosity of water is $\eta = 8.9 \cdot 10^{-4}$ Pa · s.

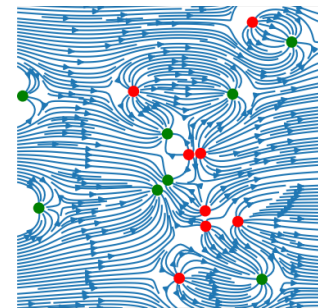
B5 An electric field E has been created in the electrolyte tank by a voltage source. This causes the ions to move in the directions indicated in the diagram. **2.5**

1. Indicate the direction of the field E
2. Find the velocities of the ions v_+ and v_-
3. Find the electric current density j and the specific conductance κ of the solution.



Neglect the influence of the ions on each other. Express your answers in terms of the ion mobilities μ_+ and μ_- and their molar concentration $c_+ = c_- = c$.

The dependence of κ on c in the previous part of the problem should be linear, so the concept of molar conductivity $\Lambda = \kappa/c$ is introduced. When studying real solutions, we observe deviations from linearity at high c . These deviations can be qualitatively explained: in constructing the theory, we did not account for the interaction between ions. As the concentration increases, the average distance between ions decreases, so ions moving in opposite directions begin to pass close to each other at small distances. The interaction between ions is Coulombic in nature, and an analogy with gravity applies: the smaller the impact parameter, the stronger the deflection. Эти отклонения легко объяснить качественно: при построении теории мы не учли взаимодействие ионов друг с другом. При повышении концентрации среднее расстояния между ионами начинает уменьшаться, поэтому двигающиеся в противоположные стороны ионы начинают пролетать на маленьких расстояниях друг рядом с другом. Взаимодействие между ионами имеет кулоновский характер и применима аналогия с гравитацией: чем меньше прицельный параметр тем сильнее отклонение. To describe only the mobility of ions (and neglect their interactions), the concept of limiting molar conductivity $\Lambda_0 = \Lambda(c = 0)$ is useful.



B6 Graph the plot of κ versus c and determine the value of Λ_0 for the sodium chloride NaCl solution. Note, that the provided water contains trace amount of other salts. **1.0**

B7 Assuming that the radii of the ions Na^+ and Cl^- are equal and denoted r , estimate its order of magnitude. **1.0**